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WETTING-AGENT CONCENTRATION IN WATER SOLUTION DETERMINED BY THE DROP-NUMBER METHOD

BY

JOHN P. HARMON

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WETTING-AGENT CONCENTRATION IN WATER SOLUTION DETERMINED BY THE DROP-NUMBER METHOD[1]

By John P. Harmon[2]

INTRODUCTION

A group of organic chemicals, known as wetting agents, has been developed, primarily for use in the textile industry. These chemicals have the property of reducing the surface tension of water when mixed with it in very dilute solutions. The advantage of lowered surface tension is recognized in dust-control work, and several wetting agents have been tried by dust-control engineers with varying degrees of success. It is well-known that certain solids, coal for instance, are extremely hard to wet with plain water because of the high surface tension of water and the water-repellent action of coal. If the surface tension of the water is reduced, it can be demonstrated that the coal can be wetted easily. This is accomplished practically and at low cost by dissolving a very small percentage of wetting agent in the water that is to be used for wetting purposes. (Care should be exercised in using a wetting agent to be sure that it will not interfere with a subsequent process.)

For some time the comparative efficiency of various wetting agents has been the subject of considerable work by dust-control men at coal mines, as well as by members of the Bureau of Mines [3] [4] [5] [6] In this connection, a number of samples of air-borne dust have been collected in the mines. With the exception of dust-control measures, conditions of dust generation and dissemination were maintained as nearly uniform as possible. Samples were collected when water alone was sprayed on the cutter bar of a mining machine; various wetting agents were then successively added to the water and more samples of air-borne dust were collected.

1/ The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from the Bureau of Mines Information Circular 7351."

2/ Mining engineer, Gas and Dust Section, Health Division, Bureau of Mines, Central Experiment Station, Pittsburgh, Pa.

3/ Hartmann, Irving, and Greenwald, H. P., Use of Wetting Agents for Allaying Coal Dust in Mines: Bureau of Mines Inf. Circ. 7131, 1940, 12 pp.

4/ Owings, C. W., Some Preliminary Data on Methods for Controlling the Dust Hazards in Mechanical Mining: Bureau of Mines Inf. Circ. 7151, 1941, 12 pp.

5/ Owings, C. W., Methods of Allaying Dust in Underground Mining Operations: Bureau of Mines Rept. of Investigations 3631, 1942, 38 pp.

6/ Johnson, John A., Use of Wetting Agents in Reducing Dust Produced by Wet Drilling in Basalt: Bureau of Mines Rept. of Investigations 3678, 1943, 27 pp.

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After the atmospheric dust concentration was determined from the samples, several erratic results were noted. At times when one particular wetting agent was used, a marked reduction in dust concentration was noted. Then, under similar conditions, presumably the same concentration of the same wetting agent based on the amount of wetting agent added seemed to have no more effect than plain water. The concentration of wetting agent in the solution presumably was known; but, due to improper mixing, the concentration may not have been uniform.

To complete the data it seemed important to have some simple means for determining the concentration of wetting agent in the solution as it emerged from the nozzle. For this reason, a series of tests was made with a Traube's stalagmometer for thin liquids, to see if it could be used for making such a determination. The stalagmometer is commercially available from many laboratory-equipment supply houses.

Results indicate that the concentration of a known wetting agent can be determined within limits, close enough for control purposes and the interpretation of experimental results, by the drop-number method.

ACKNOWLEDGMENTS

The assistance of Mariagnes Verosky, laboratory technician in the Health Division, is appreciated. After reading this manuscript, Miss Verosky prepared a curve for one of the wetting agents (wetting agent B, fig. 4) and then determined the concentration of wetting agent in two solutions that had been prepared by the writer. Solution A was prepared as 0.015 percent; she reported 0.018 percent. Solution B was prepared as 0.004 percent; she reported 0.004 percent.

The interest in the method described here that was shown by H. H. Schrenk, chief, and C. E. Brown, chemist, both of the Health Division, is appreciated. Suggestions made by them were helpful in the preparation of this report.

APPARATUS AND ASSEMBLY

The stalagmometer used in these experiments (figs. 1 and 2) has a capacity of 2 ml. It is made of glass tubing and consists of a tip on which the drops of liquid to be tested are caused to form. The apparatus was designed for determining surface tension of blood, serums, etc., by the drop-number method. In general, the number of drops formed from a given volume of liquid is a function of surface tension, and the time required for a given volume of liquid to drip from the stalagmometer is a function of viscosity. In the low-concentration range of wetting agents in water, the surface tension of the liquid decreases as the concentration of wetting agent increases and viscosity is influenced by temperature changes. The number of drops per unit volume increases noticeably as the surface tension of the test liquid decreases, but the time required for a given volume of liquid to pass through the instrument varies only with change in temperature, and then only slightly. For this reason the time factor can be disregarded in the determinations.

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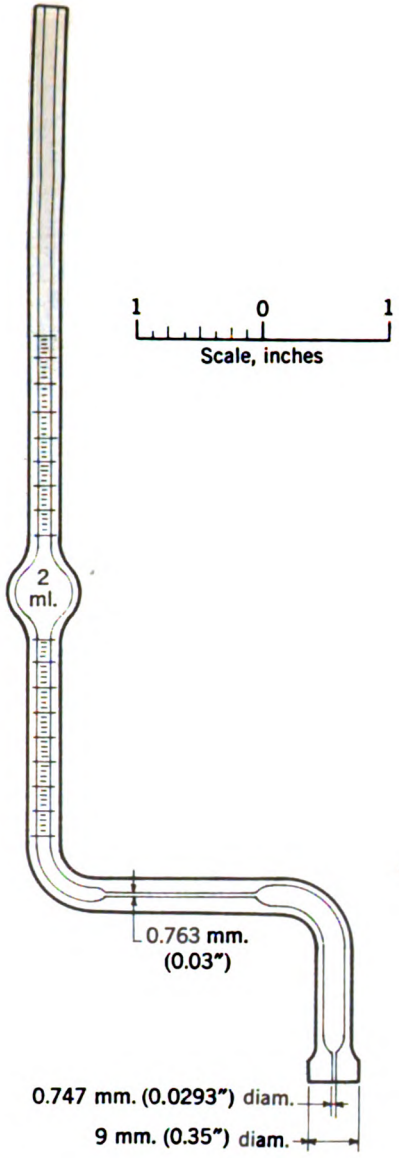

FIGURE 1.- Diagrammatic sketch of Traube's stalagmometer.

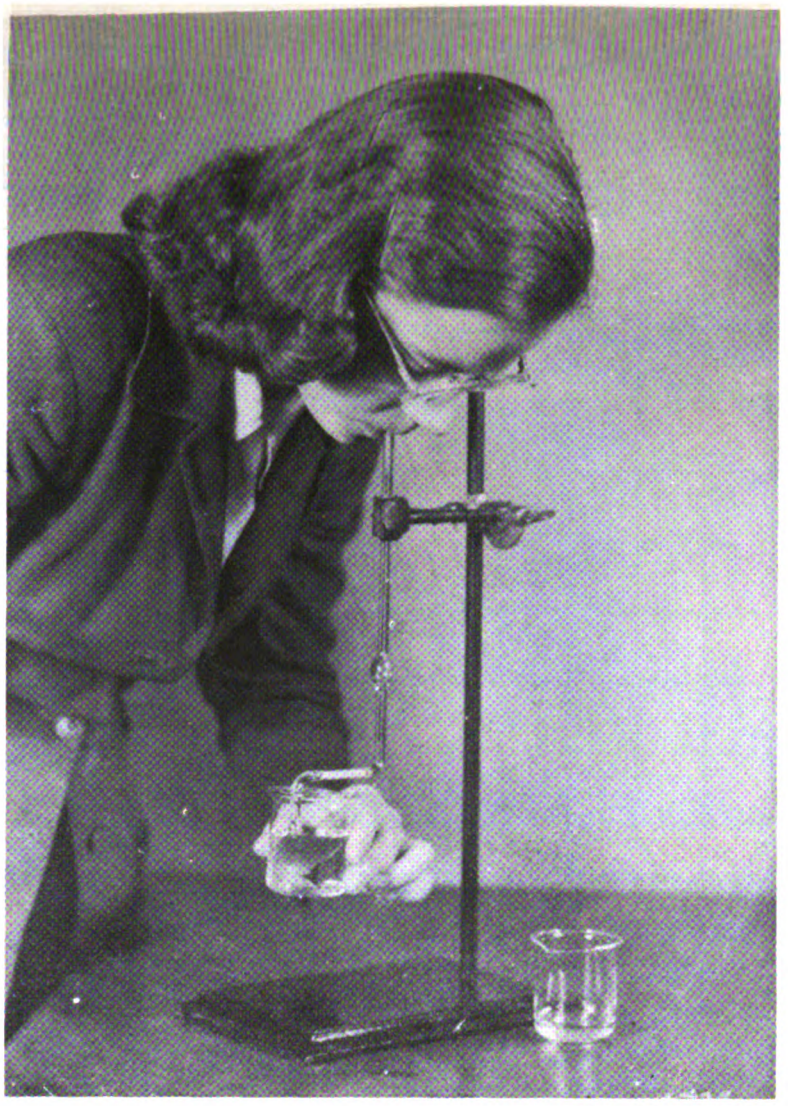

FIGURE 2.- Traube's stalagmometer in operation.

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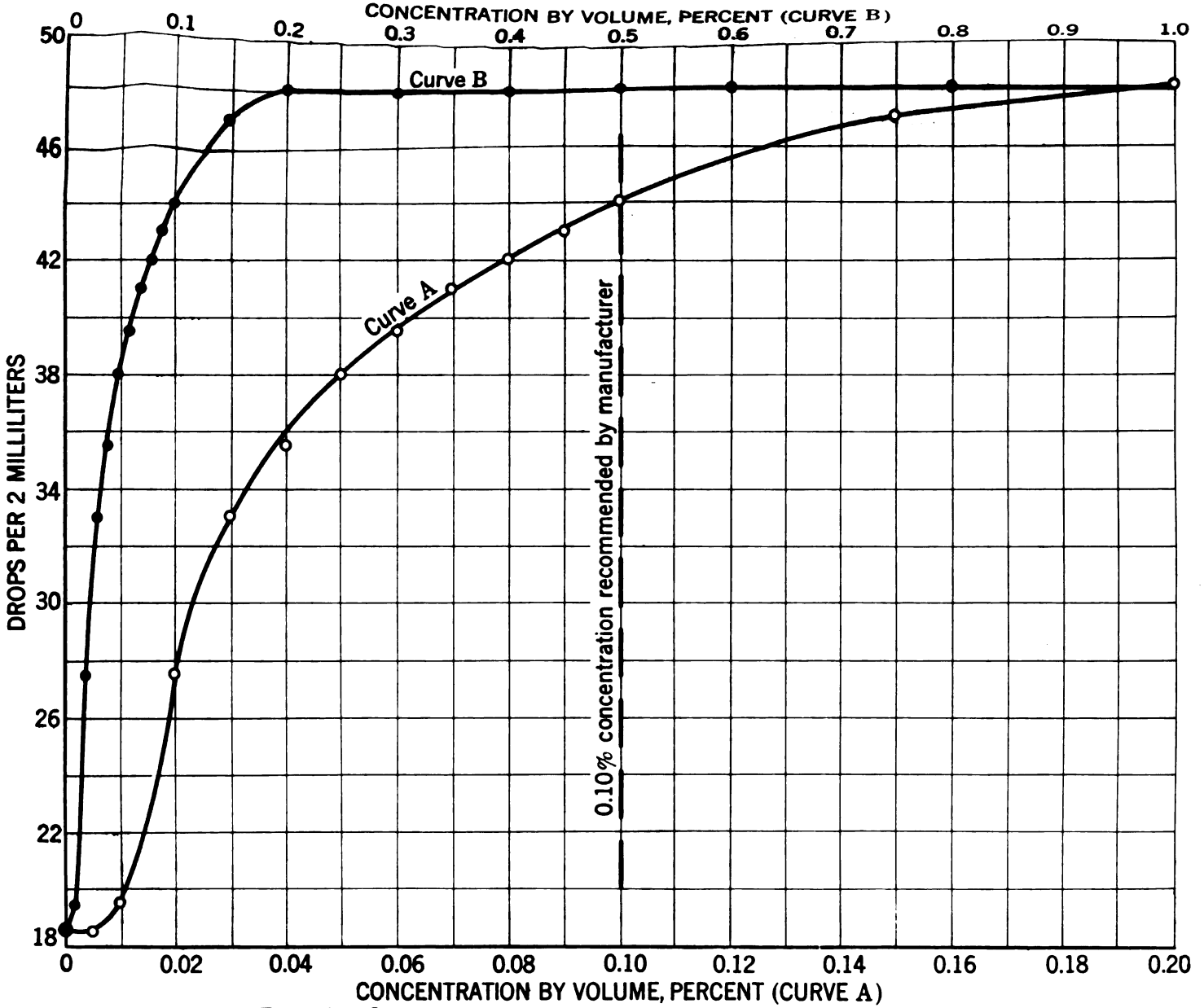

FIGURE 3.- Stalagmometer tests, wetting agent A in tap water at 83° - 84° F.

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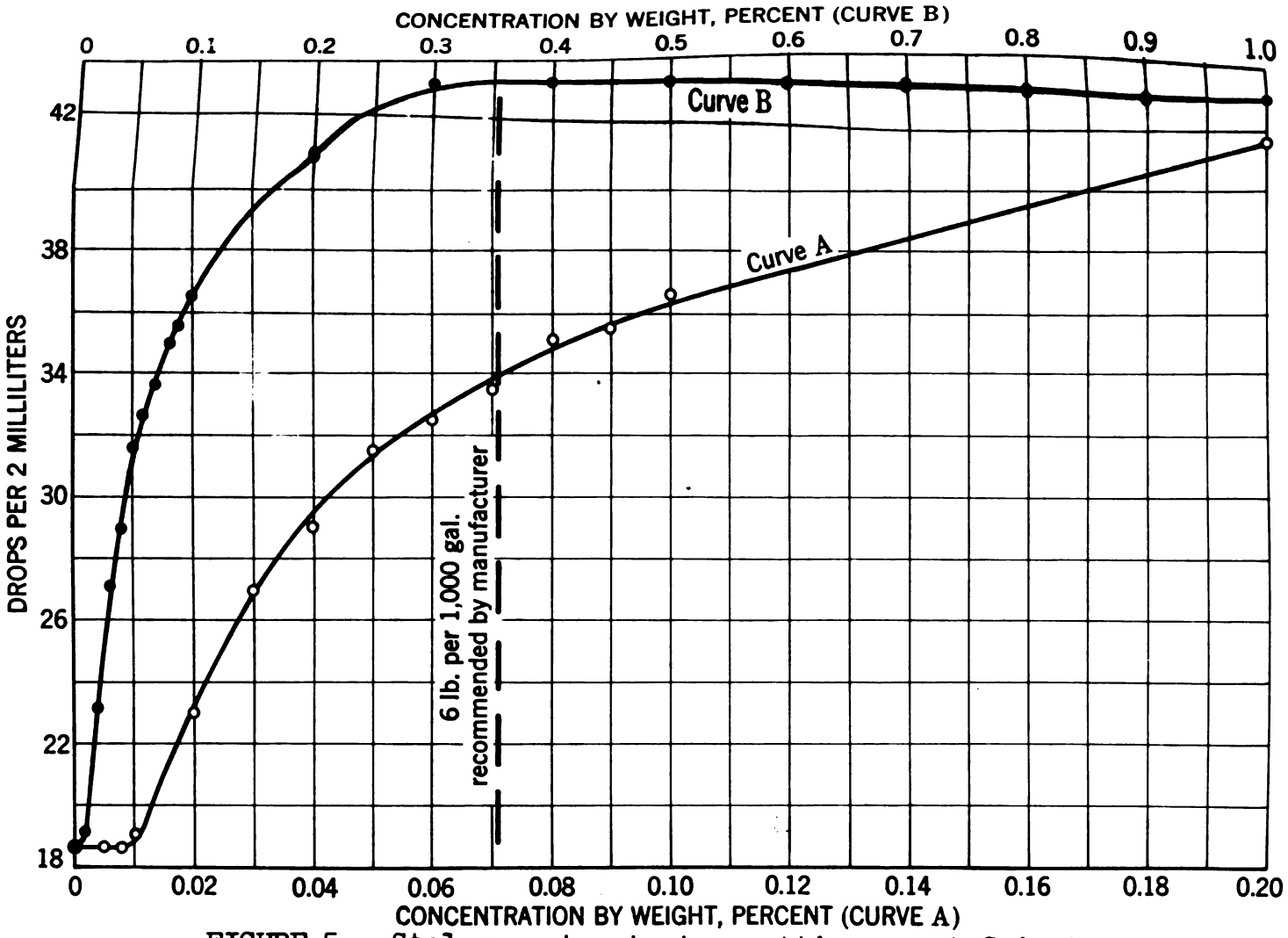

FIGURE 5.- Stalagmometer tests, wetting agent C in tap water at 80½ - 82 F.

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The apparatus should be assembled in a vertical position and all tests made from the same position (fig. 2). It should be so arranged that the polished plane of the tip on which the drop is formed is within 3° of horizontal. The apparatus should be placed so that it will not be influenced by vibration or draft.

PROCEDURE

Dilute solutions of several wetting agents, designated here by letter, were prepared in known concentrations. Tap water was used because it is more similar to water used for dust suppression than distilled water would be.

The test solution was drawn into the apparatus by suction, and a small quantity was expelled through the upper end to eliminate froth. The liquid was allowed to drop to the upper graduation, where it was stopped, and the drop that was hanging on the tip was wiped off. The liquid was then allowed to drop from the upper to the lower graduation. The number of drops formed and the temperature were noted (table 1). If a drop of considerable proportions had formed on the tip but had not fallen when the liquid reached the bottom graduation, it was recorded as ½ drop. If the liquid had flowed more slowly from the tip, it would have been possible to estimate accurately the fraction of a drop remaining on the tip by noting the number of graduations on the scale required to form one drop, but from experience this precision seems to be unnecessary. The required volume of liquid passed through the instrument very quickly; as many as 50 drops were formed in approximately 30 seconds from 2 ml. of solution.

The procedure outlined above was repeated for a number of known concentrations for each wetting agent. The results were plotted on rectangular coordinate paper, using the horizontal axis for percent concentration and the vertical axis for the number of drops. Experience indicates the concentrations that are necessary to get sufficient points to develop a smooth curve. Figures 3, 4, and 5 are curves that were prepared from results obtained in the laboratory. The circles indicate the concentrations that were used. Two curves, designated as A and B, have been plotted on each of the figures. Curve A should be used with the bottom scale of percent concentrations, and curve B with the top scale. Curve A in each case is an enlargement of the lower concentration end of curve B.

DISCUSSION OF PROCEDURE

Some variation was noted in the number of drops formed and the time required for the liquid to pass through the instrument. Experimentation indicated that these differences probably were due to changes in room temperature. The temperature of the liquid tested was determined largely by that of the stalagmometer; and this, in turn, was controlled by the room temperature. Within the temperature range available, the number of drops formed for a given concentration increased only slightly as the temperature increased, but the time required decreased as the temperature rose. For practical purposes, the temperature of the unknown solution should be within 2° F. of the temperature at which the curve was prepared. With few exceptions, this condition would prevail underground.

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TABLE 1. - Stalagmometer test - wetting agent A

Concentration by volume, percent	Drop number	Temperature, °F.
0.005	18.5 1/	
	18.5	
.01	19.5	
	19.5	
.02	(28) 2/	84
	27.5	
	27.5	
.03	33	
	33	
.04	35.5	
	35.5	
.05	(37.5)	
	38	
	38	
.06	39.5	
	(39)	
	39.5	
.07	41	
	41	
.08	42	
	42	
.09	43	
	43	
.10	44	
	44	
.15	47	
	47	
.20	48.5	83.5
	48.5	
.30	48.5	
	48.5	
.40	48.5	
	48.5	
.50	48.5	83.0
	48.5	

1/ If a drop of considerable proportions had formed on the tip but had not fallen when the liquid reached the lower graduation, it was recorded as a half drop.

2/ Values in parentheses ( ) were not plotted.

At times bubbles will collect in the angles of the stalagmometer, and it may be difficult to remove them. Repeated tests have been made with bubbles in the instrument and with no bubbles in it. The presence of bubbles seems to have no influence on the number of drops formed, provided the bubbles are not present above the lower graduation on the tube, in which case the volume of liquid to be discharged would be reduced.

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A person interested in using this method for determining the concentration of wetting agent in solution should prepare a set of solutions that vary in concentration from 0 to 0.1 percent by 0.01-percent increments, using representative samples of water and wetting agents that are used on the job. The characteristics of the wetting agent that is being tested will determine the upper limit of concentration that should be used in preparing the curve. There seems to be little purpose in using concentrations that result in repetition of the same number of drops being formed. Increments of less than 0.01 percent may be necessary for some of the more active wetting agents, as shown in figure 4, but this can be determined only by observation. The method is so sensitive that differences between tap water in the laboratory and mine water that is being used for dust suppression might cause considerable error. The samples and the stalagmometer should stand long enough to reach room (mine-air) temperature. The number of drops should be determined for each concentration and the results plotted. Such a chart should serve as long as the water remains uniform and the temperature does not vary more than ±2° F.

DISCUSSION AND USE OF CURVE

As will be noted, the curves rise from 18½ drops (for this instrument) at zero concentration of wetting agent in a curve similar in shape to a parabola to a point where the slope of the line becomes zero. It will be noted further that the concentration recommended by the manufacturer for dust-control work (figs. 3 and 5) lies below the flat part of the curve.

In determining the concentration of an unknown solution, a portion of the solution should be drawn into a clean stalagmometer and expelled to waste so that the surfaces of the tube will be wetted with the solution. A second portion should be taken and a small portion expelled through the top. The solution should be allowed to drop to the top mark and the drop wiped off the tip. The solution should then be allowed to fall freely to the lower mark and the drops counted. By reference to the curve, the concentration should be determined directly. If, however, the number of drops indicate a concentration that falls on the flat, top part of the curve, the solution should be diluted with an exact amount of the same water that was used originally, and the procedure repeated. This should be repeated until a concentration that falls on the steep part of the curve is found, and this concentration should be multiplied by the dilution factor to determine the concentration of the original sample. Such dilutions should not be necessary in mine work because the concentration of wetting agent recommended for use in dust-control work in mines usually falls on the steep part of the curve.

It is suggested that the optimum concentration of any wetting agent might be determined from such a curve. It seems likely that little increase in beneficial effect would be derived from a concentration of wetting agent greater than that which causes the maximum number of drops to fall from the stalagmometer.

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CONCLUSIONS

Traube's stalagmometer appears to be a tool that can be used for accurately determining the concentration of wetting agent in solution. Determinations can be made quickly, on the job, by a person who is not especially trained in laboratory technique. The instrument should find wide application in industry to help interpret results and control concentration wherever a wetting agent is used in a water solution.

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